Chemical Binders used in Australia

George Vorobieff
Australian Stabilisation Industry Association (AustStab)

ABSTRACT

Australia, like many other countries around the world, is gaining access to a wave of new chemical binders on the market. So how do these binders work? And is there a way of characterising them in the laboratory with a rational design approach to establish binder content and stabilisation depth?

This paper will cover the types of chemical binders in Australia, the difference between stabilisation binders and dust suppressants, common laboratory testing, their performance and future research for these binders.

CONTENTS

1. INTRODUCTION

Australia, like many other countries around the world, is gaining access to a wave of new chemical binders on the market. Some companies promote their product as the ideal maintenance and rehabilitation solution for local government and claim that where traditional binders have failed, these new binders will bring life back into the road. On further enquiry about how a particular binder works, one is sometimes told that many Councils in the local region are using it, so it must work! So how do these binders work? And is there a way of characterising them in the laboratory with a rational design approach to establish binder content and stabilisation depth?

One aspect of road maintenance and rehabilitation gaining attention in rural Australia, is the issue of dust generated from unsealed roads. Farmers have found that dust from adjacent access roads, covers leaves and produce, adversely affecting their crop yield. Chemical binders applied to unsealed roads are a simple and effective way to reduce dust generation and also minimise rutting on the road surface after rainfall.

Figure 1 Dust generation on unsealed roads in agricultural areas is becoming a concern for farmers trying to maximise crop yields.

The term stabilisation in this paper refers to the addition of a liquid or powder binder mixed into the pavement or subgrade material. Modification is considered a subset of stabilisation (Vorobieff, 2004).

Stabilising agent or additive was a commonly used to describe the addition of cement, lime or bitumen years ago, but the current term is stabilising binder. Binder does not infer however, that the binder ‘binds’ the material particles together.

This paper will cover:

- types of chemical binders in Australia
- categories that might be considered
- the difference between a stabilisation binder and dust suppressant
- the way binders work in pavement materials and subgrades
- the relative costs of binders
- laboratory testing
- trials
- the delivery of these binders
- the performance claims from binder suppliers

2. TYPES ON THE AUSTRALIAN MARKET

The following list includes some of the more common brands of chemical binders used in Australia in 2004:

Claycrete	Dustex	Dustmag/Paczyme
Endurazyme	Magchlor	Polycom
Polyroad	Renolith	Reynolds
Road Tech 2000	Roadbond EN-1	Soilbond
SoilFix	Stabileg	Top Seal
Warajay	Weslig 120	

Most of these chemical binders are supplied from one source in Australia and cartage costs can end up being a significant factor in the final supply price. The cost of these binders varies from $600 to $1,200 per tonne and whilst many require only 1 to 2% of binder (based on company literature), they have a similar price per area when compared to a slag/lime binder at $170 per tonne and at 4% application rate. This does not imply however, that application rate multiplied by cost per tonne is indicative of pavement life.

3. CATEGORIES

The 1998 edition of the guide to stabilisation (Austroads, 1998) outlined the following categories of chemical binders:

- organic non-bituminous products
- water attracting chemicals
- waste oil
- petroleum based products
- electro-chemical products
- microbiological binders
- polymers

The definition of microbiological binders in the 1998 guide (Austroads, 1998) was "… microbes into the pavement material which consume the clay fraction and excrete a polymeric residue that acts as a binder for the fines particles". This type of product has not been sold in Australia for many years and little technical information is available on the product.

The new edition of the guide has defined chemical binders in a slightly newer format as shown in Table 1. A case could also be presented to create sub-categories in the organic class such as:

- Tall oil pitch – an organic water based non-bituminous emulsion from paper manufacturing
- Sulphonated lignin – a glue powder from paper manufacturing
- d'Limonene - a by-product from citrus manufacturing

Table 1 Proposed new classification of chemical binders (Austroads, 2004).

Category	Description
Polymers	PVA, PVC polymers and copolymers bond fine particles and impart hydrophobic properties to soil. Effective in sandy soils, lime added for clays.
Organic	Sulphonated lignin, di-limonene, tall oil has a gluing action and surfactant properties. Effective in dry environments and generally require plasticity. Cement or lime can be added.
Ionic	Electro chemical charge imparted to clay platelets. Material dependent

	and slow reacting
Salts	Water attracting (hydroscopic) magnesium chloride most common. Require moisture (humidity) to be effective.
Biological	Microbes consume clay to excrete polymeric residue. High clay contents required. These types of binders are rarely used in Australia

Jones notes that lignin is a natural polymer and a major component of wood (Jones, 2001). Sulphonate lignin is produced as a by-product of the wood pulping process when the cellulose and lignin are separated. Depending on the binder supplier, it is available in either powder or liquid form.

Tall oil pitch technology utilises an emulsified form of the tall oil pitch, known as a water-based organic emulsion. The emulsion is composed of a natural mixture of natural polymers, fatty acids and rosins, and is highly tacky and hydrophobic. The water-based emulsion allows the tall oil pitch, the oily phase dispersed as tiny droplets in the water, to be readily mixable and dilutable in water. One recognised organic emulsion currently used in Australia is Soilbond.

The most common polymer is a dry powder format with or without hydrated lime. Polyroad is one such binder and has been well document in various publications (Austroads, 2003a, AustStab, 2003, GeoPave, 2003). The manufacturer has also studied its performance in the field (Lacey, 2004). Polymers are also likely to work in silty soils and sandy gravels, and this information is not noted in Table 1.

Chemical binders are either powdered or liquid based (soluble in water) and use the same equipment as used for lime and cement to apply the binder to the pavement material (see construction section). The supply format is based on the manufacturing technique for the binder and there are benefits and limitations for both liquid and powder formats.

For safety reasons, it is essential that users are familiar with the Materials Safety Data Sheet (MSDS) for the chemical binder being supplied. The following website lists over 250,000 products www.msds.com.au

4. BINDER OR DUST SUPPRESSANT

A common question by many engineers is whether the binder is a dust suppressant or stabilising agent. There is no simple answer as lime, cement and bitumen may also be used for dust suppression of unsealed roads. For instance, a road authority in western NSW uses lime stabilisation as the first stage for unsealed roads for both strength and dust suppression (see Figure 2).

Most dust suppressants are in liquid form and are applied to the surface of the unsealed road with a spray bar behind a water cart. Mixing is sometimes carried out with a grader blade and the surface compacted with light rollers.

It has been well documented that dust suppressants (Jones, 2001):

- require periodic rejuvenation to ensure continued dust suppression
- using a mix-in process will provide effective dust palliation for longer periods than spray-on treatments.

Figure 2 Unsealed road stabilised with lime to suppress dust generation and provide stiffness to carry heavy traffic loads.

CSIR Transportek has developed protocols for the assessment of binders for unsealed roads (Jones, 2003) such that the binder can be carefully checked against reference materials. After testing the stabilised material, certification is provided noting it's 'fit-for-purpose' (see Figure 3). The following individual tests were identified by CSIR as potentially suitable components for inclusion in a suite of tests for controlling binder application rate:

- Agglomeration
  - Sieve analysis
  - Wet and dry durability tests
- Resistance to abrasion
  - Pellet abrasion tests
  - Wheel tracking tests
  - Wind tunnel tests
- Resistance to erosion
- Strength increase
  - California Bearing Ratio (CBR)
  - Unconfined compressive strength (UCS)

Most chemical binders used in dust suppression fall into the salts or organic categories. These binders must have some form of glueing action or chemical charge attraction for the binder to work on the 75 µm size particles.

5. HOW DO THEY WORK?

Chemical binders vary in composition and effectiveness. The two most common soil properties that impact on chemical binders is soil plasticity and grading. A range of actions of chemical binders is known to occur and these are listed in no set order in Table 2.

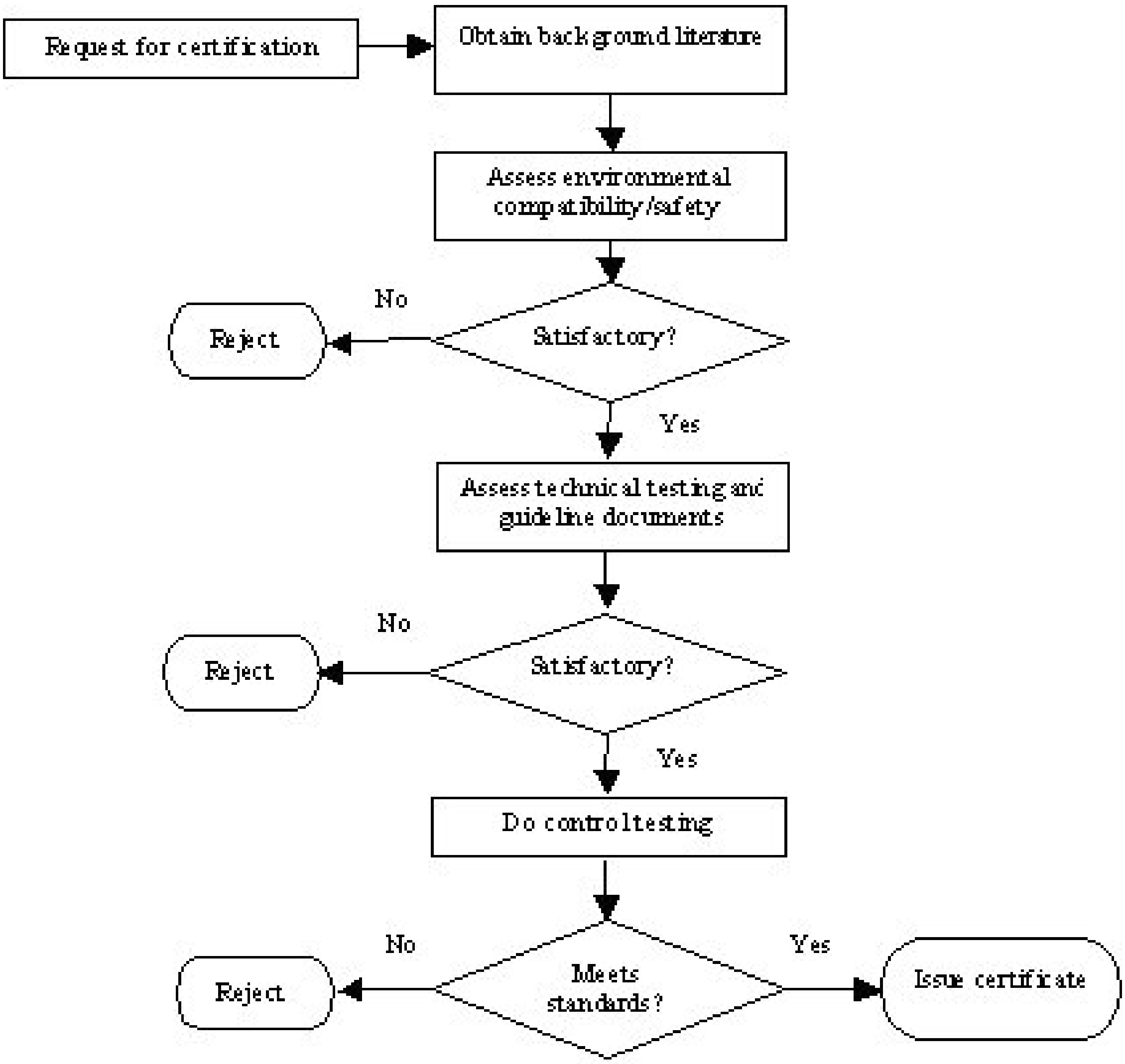

Figure 3 Recommended certification procedure from work by CSIR Transportek (Jones,2003).

Table 2 Action of chemical binders in pavement and subgrade materials.

Action	Description
Adhesion	Act as a glue in bonding particles
Adsorption:	To attract atmospheric moisture to reduce dust emission
Dilatant	To dispel water when compacted under vibration.
Dispersant	Separates fine particles from each other
Ionic	Bonding from a reversing of the electrostatic charge on some soil platelets
Surfactant	To reduce surface tension.

The typical particle size distribution preferred is shown in Figure 3. This may be used for both cementitious and bituminous binders. One could argue that chemical binders may also be appropriate for the material grading shown in Figure 4, but they tend to be used where the material is excess in fines, such as prior stream gravels used on roads in the south western region of NSW (see Figure 5).

Studies by RTA, VicRoads and Polymix also indicate that Polyroad is most suitable for fine grained pavement materials (RTA 2003, GeoPave 2003, Lacey 2004). This is typically referred to as particles passing the 425 µm sieve. Little information is available to provide a minimum guideline but is anticipated that at least 40% of the pavement material or subgrade should contain fine grade materials (ie material passing the 2.36 mm sieve).

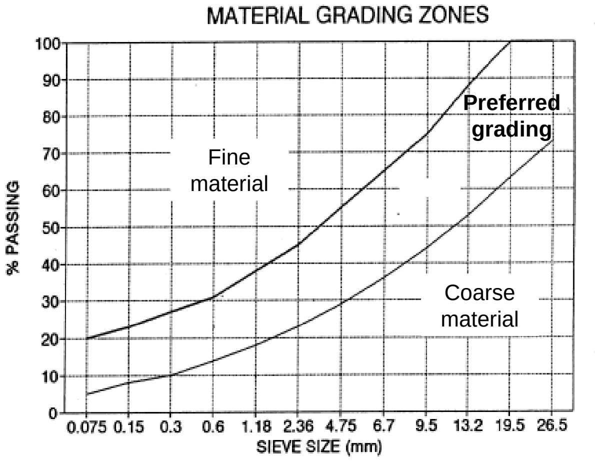

Figure 4 Good particle size distribution is required to achieve strength and durability (Austroads, 2002).

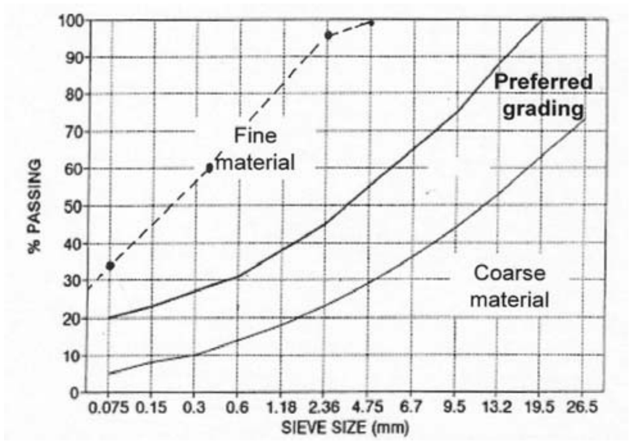

Figure 5 Particle size distribution (dashed line) of prior stream gravel from SW region of NSW (Kok, 2003).

As noted in Austroads, 2004, chemical binders are generally suited:

- surface bonding and moisture penetration resistance on unsealed road surfaces
- assisting with compaction in marginal pavement materials and subgrades
- reducing compaction water demand
- helping to disperse cementitious binders in high fine content materials
- reducing plastic shrinkage in cement stabilisation
- working as an anti-strip in bitumen stabilisation

It should be noted that many chemical binders may be subject to leaching and/or biodegradation over time so their binding effect could be lost. Long-term strength results from laboratory testing in the future may provide some indication of whether the binding action is temporary or more permanent.

Finally, the pavement designer has to choose a binder that suits the existing pavement material and depth in the pavement structure. The designer may take a conservative approach and target the stabilised material to remain unbound (or granular) or add a sufficient quantity of binder to ensure that the material becomes modified (see Table 3). Some chemical binders sold in Australia combine cement with the chemical and when mixed and compacted, this binder may result in a lightly bound material.

6. PERFORMANCE CLAIMS

The behaviour and limitation of lime, cementitious and bituminous binders is well known and documented from decades of research work and application of these binders from a range of roads across Australia. As new binders become available, such as those imported from overseas, the supplier tends to adopt similar advertising and technical literature from the country of origin. Poor pavement terms and limited data leave some engineers bewildered.

Table 3 Proposed classification of stabilisation materials for Austroads guide (Austroads, 2004).

Type of Stabilisation	Typical binders adopted	Performance attributes
Granular 40% < CBR < +120%	Blending other granular materials which are classified as binders in the context of this Guide.	Flexible pavement subject to shear failure within pavement layers and/or subgrade deformation
Modified 0.7 MPa < UCS* < 1.5 MPa	Addition of lime. Addition of polymer or chemical binders.	Flexible pavement subject to shear failure within pavement layers and/or subgrade deformation. Can also be subject to erosion by water penetration through cracks.
Lightly Bound 1.5 MPa < UCS* < 3.0 MPa	Addition of small quantities of cementitious binders. Addition of small quantities of bituminous or bituminous/cementitious binders.	Lightly bound pavement which may be subject to tensile fatigue and/or subgrade deformation. Can also be subject to erosion by water penetration through cracks.
Bound UCS* > 3.0 MPa	Addition of higher quantities of cementitious binder. Addition of a combination of cementitious and bituminous binders.	Bound pavement subject to tensile fatigue cracking and transverse drying shrinkage cracking. Less likely to be subjected to erosion by water penetration through cracks.
Note: UCS test specimen prepared using standard compactive effort and 28 day normal curing.		

Chemical binder suppliers have provided a variety of performance claims[1], such as:

- The products designed to work in Yards and Hardstand areas are subjected to the rigors of forklifts weighing up to 72 tonnes and handling 38 tonne containers. The point loadings of this equipment are severe and the product performs exceptionally well in these environments.
- By increasing particle repulsion by 'chemical dispersion', chemical soil stabilisers decrease the apparent particle size, ie breaks down the aggregates.
- Can be applied to most soil types including sandy soils and clays.
- Used usually upon trafficked areas such as roadways, it acts as a compaction agent
- Prevention of ingress of moisture
- The limits of the product are only limited to the innovative creation of the design engineer and the resources available.
- Substantially increasing the resilient strength and elastic modulus of the base.

One of the challenges with claims made by companies promoting chemical binders is that they are often accompanied by overseas test results with limited information about the material tested and the exact protocols for the test method. For example, if a sample is tested for UCS in Australia using AS 1141.51, several methods of compaction may be used. Each compaction method will result in a unique result, and many samples in Australia are also tested after a 4-hour soak. The difficulty in comparing overseas test results with known Australian test methods and design models are obvious!

When you examine one of the claims '… increasing the resilient strength and elastic modulus ..' there also seems to be poor use of terminology as the pavement actually needs to have sufficient stiffness to carry the traffic and environmental loading. Stiffness in a structural framework, is modulus multiplied by the structural shape, or as structural engineers refer to stiffness, as 'EI'. The structural shape is a made up of the depth and breadth in pavements, and depth is the dominant component in 'EI'. Therefore, increasing 'resilient modulus' and not 'resilient strength' is important but should be limited according to the depth of the pavement and strength of subgrade support.

Several binder suppliers claim to reduce moisture ingress compared to granular materials. A granular material over a subgrade not only protects the subgrade material from wheel loading leading to deformation, but must also prevent ingress of water or moisture. The main methods in which moisture can enter a pavement and subgrade are:

- rainfall infiltration through the wearing surface
- surface water forced through cracks in the wearing surface by repetitive action of vehicle tyres
- groundwater seepage in a cutting or near agricultural channels
- capillary water from the verges or from a water table
- vapour movements from below the wearing surface
- lateral movement of moisture from pavement materials in the road shoulder

If a claim is made to prevent moisture ingress then consideration should be given to how the stabilised material may perform under the above methods of moisture ingress.

The elimination of shrinkage cracking in the use of cement and cementitious stabilisation is a noble goal for pavement engineers. However there are many examples where well mix designs for cement stabilisation has resulted in no visible shrinkage cracking on the surface of 30 mm of an asphalt wearing course for over six years after construction. One aspect that needs to be considered in shrinkage cracking is the properties of the parent material before stabilisation and

[1] The reference to the claims are not provide as to avoid commercial advertising.

how to control the introduction of moisture into the mixing process. In some cases, longitudinal shrinkage cracking has appeared as a result of too much water being introduced into the overlap mixing zone due to the use of sub-standard equipment by the contractor. Applying moisture from a spray bar behind a water cart over the uncompacted surface of the material can lead to overdosing or flooding and the result is shrinkage cracking.

7. LABORATORY CHARACTERISATION

Laboratory characterisation of stabilised pavement and subgrade materials using chemical binders is based according to pavement layer. For instance, subgrade materials are typically required to support the subbase and base layers, and the two main criteria are moisture sensitivity and CBR. In a base layer, permeability and modulus are important criteria.

For granular material, Table 4 summarises typical defects in granular pavement materials. Traditionally, chemical binders are used for pavement materials to produce an unbound or modified material (see Table 3) rather than producing a bound state. One would therefore expect that chemical binders should aim at improving one or more of deficiencies noted in Table 4.

Table 4 Pavement deterioration categories and causes (Austroads, 2003b).

Category	Typical Deficiencies	Typical Causes
Break-up soon after construction	rutting cracking shoving peeling potholing ravelling	Inadequate compaction, compaction of over-wet base, Poor surface for priming Poor sealing technique Load induced pore pressure
Formation dependent	cracking subsidence longitudinal cracking	Seepage Settlement or failure of fill Settlement or failure of fill
Edge dependent	outer wheelpath crack or distortion or rutting edge cracking edge breaking and drop-off	Moisture in subgrade, poor base material, overloaded vehicles, poor compaction, inadequate layer thickness. Inadequate pavement width, poor shoulders, poor seal
Season dependent	longitudinal cracking potholing	Expansive clay subgrade, moisture entry seal cracking
Long term	rutting roughness cracking ravelling weathering	Inadequate layer thickness or base material strength Inadequate layer thickness or embrittled seal coat Embrittled seal coat

Common tests performed on chemical binders include:

- CBR
- Unconfined compressive strength
- Capillary rise and swell
- Permeability
- Leaching

A challenge with the above tests is to establish an appropriate curing and preconditioning of the sample prior to testing. Cementitious binders are cured using either 28-day standard curing conditions or accelerated curing at 65°C for 7 days (Austroads, 2002). In both cases, the preconditioning of these samples prior to UCS testing is to soak the samples in a water bath for 4 hours.

On examination of various technical reports from chemical binder suppliers, a new generation of curing systems have been developed. Some require accelerated curing and others require exposure to ultraviolet light for 7-days. Accelerated curing of chemicals (other than bitumen and cement) by increasing the temperature of the environment is of great concern as the reactions that take place at 65°C may not be the same as experienced in the field. The sample in the laboratory is likely to have more favourable characteristics due to the elevated temperature. More work is therefore required to better understand the chemical reactions that the various binders undergo with soil particles under high temperature exposure.

The above tests are currently being used to compare untreated and stabilised materials, and will ultimately establish an appropriate binder application rate with the pavement or subgrade material.

With the new Austroads pavement design guide (Austroads, 2001) limiting the maximum subgrade design strength to 15%, the target average laboratory CBR strength is about 30%. So claims by companies of reaching 120% CBR is of no value in a design model that limits the design subgrade strength to 15%.

A greater emphasis on repeated load triaxial testing to determine resilient modulus and permanent deformation of laboratory testing is occurring for granular materials, and this is also likely to occur for the stiffness properties of materials stabilised with chemical binders. Whilst draft AS1289.6.8.1 is being used and refined by road authorities and industry to determine the modulus and permanent deformation of granular materials, there are no material limits for the designer at this stage from this test. But at least the retention of the laboratory results and application of the mix design properties in the field should allow engineers to refine the design models using strength and deformation as suitable criteria.

Other laboratory tests have been developed to try and measure the effect on water on these stabilised materials. For instance, Transport SA has developed an empirical test determining the effectiveness of a stabilised material under a water drip line (see Figure 6). The measure for the effectiveness of the binder is determined by the time the specimen collapses under an annular surcharge. This method has been developed with particular reference to the evaluation of the suitability of various types of chemical binders.

8. CONSTRUCTION PRACTICES

It is disappointing to see promotional material for chemical binders which sometimes recommends the application of the binder by ripping and grading. With application rates in the order of 0.5% to 1.5% by mass of pavement material, the use graders to mix such low quantities is unrealistic. Austroads, various Australian road authorities and AustStab specifications all recommend the application of these binders using specialist spreaders and stabilisers (Austroads, 2003a).

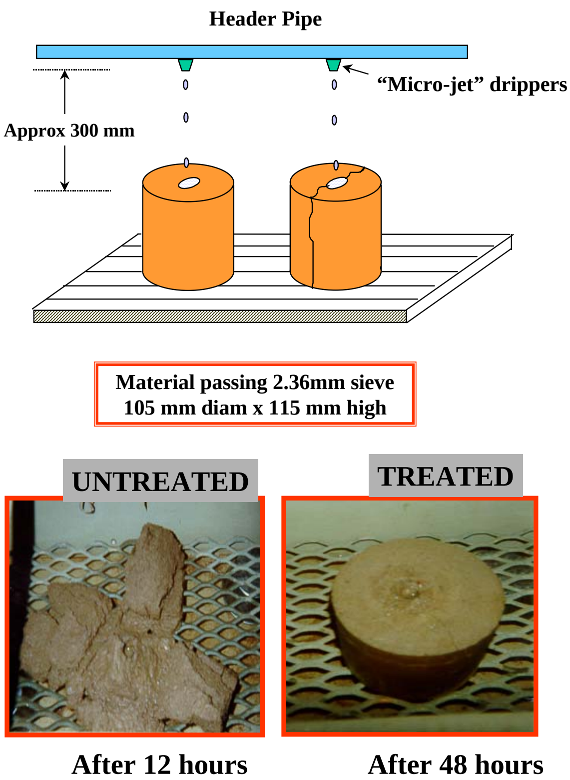

Figure 6 Transport SA saturation test apparatus (Austroads, 2004).

In Australia, trials of new chemical binders appear every month however the performance assessment is often difficult as industry concerns include:

- some control but poor documentation of the insitu materials prior to stabilisation
- lack of site investigation of subgrade properties
- minimal laboratory testing
- dubious specifications used to construct the trials

Another concern about chemical binders trials, is that the road authority engineer often selects a site where other rehabilitation treatments have not worked. Selecting a site under the worse conditions should not be considered a trial but a 'lucky dip' treatment. AustStab and its members are now developing the protocols for the application of trials for chemical binders such that the trial can be appropriately assessed.

The RTA conducted controlled trials of Stabileg and Polyroad on the Pacific Highway just north of Port Macquarie in July 2003 (Ng, 2003). The 20-year design traffic for this section of the Highway is 5.5×10^7 ESAs and a variety of pavement materials are used along the highway, including concrete. Laboratory testing of these binders has been conducted and it is anticipated that coring of the pavement materials will occur after 12-months. These well managed trials are likely to lead to sound conclusions being drawn from the performance of the binders used on this project.

The application of powder chemical binders is similar to cementitious stabilisation in that the spread rate is calculated by multiplying the application rate by the pavement depth by the maximum dry density of the pavement material and expressed as kg/m^2 (AustStab, 1997). Spread rates by volume should be avoided as this leaves the conversion to application rate (by kg/m^2) by the contractor and open to interpretation depending on the specific gravity of the binder and density of the pavement material.

Because of the small tonnage of binder generally used on projects, many chemical powdered binders are supplied in bulker bags as shown in Figure 7 or liquid binders in intermediate bulk containers as shown in Figure 8. The content of these 1 to 2 tonne bags are transferred to a spreader to allow efficient spreading of the binder. For larger projects, bulk tankers are used for delivery.

Figure 7 Bulker bags being prepared for lifting by crane to transfer the binder into a specialist spreader.

Figure 8 Intermediate bulk containers for chemical liquid binders.

Where the chemical binder is applied in a liquid form, the application rate is a little more difficult unless two water carts are used on site. In Australia, where the pavement material is typically well dry of the Optimum Moisture Content (OMC), additional water is required to increase the moisture content to achieve maximum compaction. Contractors tend to mix the material on the left side of the OMC curve rather than the right, to avoid the use of dry-back techniques before sealing or else risk damaging the road surface from traffic prior to sealing.

The increase in the moisture content may vary along the road and the 'correct' amount is typically determined after mixing with an operator walking behind the stabiliser using the hand-squeeze method. If one water cart is used to supply the liquid binder and water, the application rate of the chemical binder will exceed the minimum rate where additional water is used for compaction requirements. Therefore, if a pavement material is dry during construction, the application rate will exceed values greater than specified and presumably increase the construction costs. Conversely, if the pavement material is wet at the time of construction, applying more water is likely to take the insitu moisture content above the OMC and the pavement material will need to be dried back to minimise shrinkage cracking of the pavement material as the moisture content drops to the equilibrium moisture content.

Care must be taken at the overlap of longitudinal runs where the spray bar in the mixing chamber must be controlled to avoid double application rate of the binder in the overlap region.

Claims that chemical binders aid compaction have not been substantiated by controlled laboratory testing. To maximise compaction and reduce voids in the material, the appropriate particle size distribution and moisture content of the material is required. It is possible that some chemical binders widen the moisture density curve which may be interpreted as aiding compaction. In this instance, correcting the moisture content for the determination of relative compaction is extremely important.

Weaker aggregates that tend to break down under the vibration of pad foot rollers will also prevent the contractor reaching maximum compaction levels. Whether this is a benefit or limitation to chemical binders is uncertain.

Another aspect with chemical binders is to establish whether they leach or not after mixing and compaction (see Figure 9). Some Australian trials have shown that certain chemical binders tend to leach when the moisture content of the pavement material is close to or above the OMC. The current practice is to test for leaching using Standard AS 4439.3.

Figure 9 Leaching of a chemical binder during construction that needs attention.

Although compliance of chemical binders is an uncertain area, the compliance measures for cementitious and bituminous binders are:

- Cement or bitumen application rate
- Grading and moisture content for plant mix materials
- Depth of stabilised layer
- Relative density
- Surface levels
- Ride quality (where applicable)

Most of these requirements should be applicable to chemical binders used for stabilisation.

There are no known dedicated specifications for chemical binders and AustStab is currently addressing the lack of dedicated model specifications for powdered and liquid chemical binders.

9. FURTHER RESEARCH

For a new chemical binder to be used successfully in Australia, a series of protocols needs to be established where the chemical is used as:

- a dust palliative
- a binder to improve a granular material and remain unbound
- to impart some binding and form a modified pavement material

With these protocols non-structural tests will be required to assess:

- capillary rise
- swell
- leaching
- erosion
- durability

Some of the above laboratory tests are now being used in Australia to characterise the non-structural properties of materials mixed with chemical binders. The opportunity to get a testing program with sensible results will rely heavily on the compaction and curing of the sample material. More research is required to assess the duration and conditions of curing.

It is well known that the mechanistic design model in the Austroads guide assumes the traffic life of a granular material on a subgrade will fail due to subgrade rutting. As vehicle loads and tyre pressures increase, there is greater potential for the granular material to rut and the design model does not currently provide a suitable estimate of the pavement life. There is increasing use of structural type laboratory testing of unbound materials, including the application of chemical binders, to characterise the structural properties. Road authority laboratories will hopefully finalise the laboratory testing protocols for the determination of resilient modulus and permanent deformation (AS1289.6.8.1) such that the Standards becomes approved for use by road authorities and industry.

Another question is how to rehabilitate the existing pavement materials when they come to the end of the design traffic life? Can these materials be recycled again? Further trials with chemical binders are required to consider how these pavements can be recycled again, to reduce reliance on quarried materials and to keep the pavement open for another 20 years.

10. CONCLUSIONS

This is probably the first independent review of the use of chemical binders in Australia over the last 10 years. The usage of chemical binders has increased significantly over the past decade and established binders, such as Polyroad, now have a proven success record with a range of road environments. Although there is visual evidence that binders such as Polyroad are working, further quantitative results are required to assist in the formulation of a design model.

Water based organic emulsion binders in Australia, like Soilbond, are involved in road authority and independent laboratories to develop test protocols in order for appropriate material and pavement designs to be used by pavement designers.

Chemical binders in the future need to be environmentally friendly and those that leach into the pavement and subgrade layers are likely to have a limited sales success.

This paper also advocates the development of a concise laboratory protocol to assist with the determination of the predicted life of a stabilised material using a chemical binder. With sound laboratory testing, binder suppliers will need to justify the use of their product for any given project. The use of net present worth model also provides a good comparison between binder types for a specific pavement life.

Finally, road engineers should request Australian laboratory test results when being encouraged to trial a new chemical binder, and ignore the promotion by some suppliers of poor construction practices such as using graders and rippers for mixing.

11. REFERENCES

Andrews, R (2001) *Opportunities for improved unsealed road asset management with chemical stabilisation* Proceedings from 20th ARRB Conference, Melbourne.

Austroads (1998) *Guide to Stabilisation in Roadworks* Sydney.

Austroads (2001) *2001 Austroads Pavement Design Guide (Final Draft) for Public Comment* Report No. AP-T10, Sydney.

Austroads (2002) *Mix design for stabilised pavement materials* Report No. AP-T16, Sydney.

Austroads (2003a) *Guide to best practice for the construction of insitu stabilised pavements* Sydney.

Austroads (2003b) *Granular Materials for Pavement Construction – Part 1: Factors Influencing Performance* RC2524- Draft for Public Comment, Sydney.

Austroads (2003c) *Dry powdered polymer stabilising binder* APRG Technical Note 14, Sydney.

Austroads (2004) *Guide to Stabilisation in Roadworks* Draft version (Not published), Sydney.

AustStab (1997) *Verification of binder spread rate for insitu stabilisation* Technical Guideline Version B, Australian Stabilisation Industry Association, Artarmon, NSW.

GeoPave (2003) *Stabilisation of pavement materials using dry powder polymer stabiliser* Report No. GR02700, VicRoads, Burwood East.

Jones, D and Mitchley, M (2001) *A reassessment of the use of ligno sulphonate as an additive for unsealed roads* Proceedings from 20th ARRB Conference, Melbourne.

Jones, D and Emery, S (2003) *The development of a research protocol and fit-for-purpose certification for road additives* Proceedings from 21st ARRB Conference, Cairns.

Kok, L (2003) *Private Communication* Roads & Traffic Authority (NSW), Wagga Wagga.

Lacey, G (2004) *Do dry powdered polymers work?* Proceedings from stabilisation of road pavements seminar, NZ Highway Institute of Technology, Auckland, NZ.

Ng, S (2003) *Presentation to APRG Stabilisation Working Group* Roads & Traffic Authority, Road Services, Port Macquarie Office, NSW, August.

RTA (2003) *Pavement modification using Polyroad* Towards Best Practice, Sydney.

Standards Australia (1996) *Methods for sampling and testing aggregates - Unconfined compressive strength of compacted materials* AS 1141.51

Standards Australia (1997) *Wastes, sediments and contaminated soils - Preparation of leachates - Bottle leaching procedures* AS 4439.3

Standards Australia (2002) *Methods of Testing Soils for Engineering Purposes: DRAFT Method 6.8.1: Soil Strength and Consolidation Tests – Determination of the Resilient Modulus and Permanent Deformation of Granular Unbound Pavement Materials* Draft AS1289.6.8.1.

Vorobieff, G (2004) *Modification versus bound pavements* Proceedings from stabilisation of road pavements seminar, NZ Highway Institute of Technology, Auckland, NZ.

Acknowledgements

The author would like to thank Glenn Lacey (Polymix Industries) and Jacqueline Wong-Fat (Huntsman Chemical Company of Australia) for their input into the preparation of the paper.